ORIGINAL ARTICLE

Changes in performance, skinfold thicknesses, and fat patterning after three years of intense athletic conditioning in high level runners

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Objectives: To determine if the changes in specific skinfold sites induced by intense athletic conditioning over a three year period were associated with changes in running performance in high level athletes.
Methods: Thirty seven top class runners (eight male and five female sprint trained, 16 male and eight female endurance trained) volunteered to participate in the study. The athletes were divided into class A (n = 18) and class B (n = 17), with class A having the best performance. Biceps, triceps, subscapular, pectoral, iliac crest, abdominal, front thigh, and medial calf skinfold thickness and the best running performance were recorded at the beginning and after one, two, and three years of training. A one way analysis of variance and a linear regression analysis were conducted to determine changes and association between performance and skinfold thicknesses. Analyses were controlled for sex, sprint event or endurance event, and class.
Results: Training resulted in a significant increase in performance and decreases in sum of six skinfolds, abdominal, front thigh, and medial calf skinfolds, and the ratio of extremity to trunk skinfolds (E/T, triceps, front thigh, medial calf/subscapular, iliac crest, abdominal). There were no significant differences in body weight. Except for the abdominal skinfold, there was no significant difference in trunk skinfolds. Significant differences in these changes were observed by sex for E/T, which decreased and increased in male and female runners respectively, and by class. Class B runners significantly improved performance, with decreased skinfold thicknesses in the lower limb. There were no significant changes in performance or skinfold thicknesses in class A runners. Improvements in performance were consistently associated with a decrease in the lower limb skinfolds.
Conclusions: On the basis of these findings, anthropometric assessment of top class athletes should include an evaluation of all skinfolds. The loss of body fat appears to be specific to the muscular groups used during training. The lower limb skinfolds may be particularly useful predictors of running performance.

Research has indicated that appropriate sport specific levels of relative fat and fat-free weight are beneficial to performance in most sports.[1–4] In runners, an excess of adipose tissue usually requires a greater muscular effort to accelerate the legs, and, in theory, the energetic expenditure at the same velocity would be higher. Nevertheless, very few studies have reported the relation between body fat or sum of skinfolds and running performance in homogeneous groups of elite athletes. Conley and Krahenbuhl[5] reported no significant relation between body fat or sum of skinfolds in an elite group of 10 000 m runners (mean best time 32:06 (minutes:seconds); coefficient of variation (CV) = 3.1%). Kenney and Hodgson[6] reported similar findings in a homogeneous group of elite 3000 m steeplechase runners (mean best time 8:38; CV = 1.2%). However, a more recent study by Legaz and Serrano[7] found that skinfold thicknesses of the lower limb were positively associated with running time in the 1500 m and 10 000 m in men (1500 m, mean best time 3:43.35; CV = 2.3%; 10 000 m, mean best time 28:57.14; CV = 3.4%) and in the 400 m race distance for women (mean best time 55.13 seconds; CV = 3.4%). Only occasionally have previous studies reported the expected significant associations in more heterogeneous groups.[8–11] However, as far as we are aware, only Legaz and Serrano[7] have reported correlations between specific skinfold measures and running performance. They observed an apparent divergent association between trunk and extremity skinfolds with running performance. It is acknowledged that a cross sectional study cannot exclude the possibility that some athletes excelled in an event because they had been preselected by some special genetic endowment that could have included the extremity skinfolds. Therefore the association between performance and skinfold thicknesses may not reflect entirely a causal effect of athletic training on skinfolds. It remains to be established if this association is determined genetically, by diet and intensive training, or by a combination of these factors.

Despite the fact that a number of reports have addressed the question of body fat changes in response to seasonal training and/or competition,[12] the changes in body fat and performance have not previously been correlated. Furthermore, no particular body fat trends have been established with respect to sex differences, different seasonal physical work and/or type of training, and performance level.

Therefore the purpose of this study was to determine if the changes in sum of skinfold thicknesses and specific single skinfold sites induced by intense athletic conditioning over a three year period were associated with changes in competitive running performance in homogeneous groups of male and female high level athletes.

METHODS

Participants and study design

The participants for this study were 24 male and 13 female runners who had engaged in intense athletic conditioning over a three year period. Participants attended the National

Abbreviations: IAAF, International Amateur Athletics Federation

Table 1 Changes in running performance induced after three years of intense athletic conditioning in male and female sprint trained runners

	Male (n = 8)			Female (n = 5)		
	n	Initial measure	After 3 years	n	Initial measure	After 3 years
100 m	4	10.79 (0.2)	10.52 (0.1)	2	11.53 (0.0)	11.39 (0.4)
400 m	4	47.15 (1.4)	46.81 (1.5)	3	54.7 (3.2)	53.4 (1.7)

Data are mean (SD). Race time is presented as the official score of the International Amateur Athletic Federation.

Centre of Sports Medicine, Madrid, Spain where all anthropometric data were recorded. All examinations were performed during the competitive season within two months of the best performance as well as at the beginning, and after one, two, and three years of training.

The runners were classified into groups according to their best performance capabilities according to event: sprint trained (table 1), 100 m and 400 m; endurance trained (table 2), 800 m, 1500 m, 3000 m, 5000 m, 10 000 m, and marathon. For each event the athletes were divided into class A, which included half of the athletes (n = 18) with the best performances, and class B, which included the remaining athletes (n = 19). In those events with only one athlete, the runner was categorised as class A or class B according to whether he/she fell above or below the 50th centile of the International Amateur Athletics Federation (IAAF) scoring tables.[13]

The IAAF scoring tables were also used to measure the changes in running performance with long term training. In this system, using a database of performances obtained at world level, the IAAF assigns a score to each performance. This enables the different performances in different events for the same athlete to be assessed and compared.

Inclusion criteria for this study required at least two years of regular competition at national or international level. Twelve male and eight female subjects were Olympic athletes. Furthermore, the mean velocity achieved during the best performance of the season had to be included among the best 50 ever in the Spanish rankings. All athletes trained six or seven days a week (20–25 hours) during the season. The deconditioning period was less than one month each year.

Anthropometric variables

For each anthropometric assessment, participants reported to the laboratory on a morning after a 12 hour fast. Skinfold thickness was measured, by the same experienced investigator, at the biceps, triceps, subscapular, pectoral, iliac crest, abdominal, front thigh and medial calf. Skinfold fat data were obtained using Holtain skinfold callipers (Holtain, Crosswell, Crymych, UK) and recorded to the nearest 0.2 mm. The upscale pressure of the calliper was checked according to the manufacturer's specification, and was constant at 10 g/cm^2. Measurements were taken three times on the right side, and the mean of three measurements was used for the analyses. The use of the mean of three measurements and median did not affect the findings. The technical error of measurements (TEM), interobserver and intraobserver, was less than 5% for skinfolds and less than 2% for the other measurements.

The skinfold measurements were recorded on the fourth second after application of the calliper as this has been shown to improve the reliability of measurements.[14] This varies slightly from the method recommended by the International Society for the Advancement of Kinanthropometry, which indicates that measures should be recorded after two seconds to standardise any changes due to compressibility of the skinfold. The locations for all skinfolds have been described by Hawes and Martin.[15]

Following the recommendations of the Spanish Group of Kinanthropometry, relative adiposity indexes were calculated from the sum of the six skinfolds: triceps, subscapular, iliac crest, abdominal, front thigh, and medial calf. Relative fat patterning was also assessed by the distribution of subcutaneous skinfolds on the body: extremity (triceps, front thigh, medial calf)/trunk (subscapular, iliac crest, abdominal) skinfold ratio (E/T).

Statistical analysis

Statistical analysis was performed with the Statistical Package for Social Sciences (SPSS), version 12.0. Data are expressed as mean (SD). Significant differences in performance and skinfolds over a three year period were compared using non-parametric one way analysis of variance (Friedman). Changes in performance and skinfolds were assessed using the paired Student's *t* test and Wilcoxon signed ranks test. α was adjusted by the Bonferroni correction technique where appropriate. To assess the relation between changes in performance and changes in skinfolds, a linear regression analysis was conducted. This analysis also included sex, sprint event, or endurance event factors as dummy variables. The α level was set at 0.05.

Table 2 Changes in running performance induced after three years of intense athletic conditioning in male and female endurance trained runners

	Male (n = 16)			Female (n = 8)		
	n	Initial measure	After 3 years	n	Initial measure	After 3 years
800 m	7	1:51.3 (2.8)	1:47.4 (1.7)			
1500 m	3	3:47.0 (2.2)	3:38.2 (3.8)	3	4:17.3 (9.7)	4:23.5 (19.0)
3000 m	2	7:53.9 (11.1)	7:46.2 (7.0)			
5000 m	1	13:32.9	13:24.9			
10000 m	1	28:51.0	29:27.1	1	34:04.9	32:27.5
Marathon	2	2:15:11 (169)	2:13:34 (233)	4	2:36:04 (403)	2:34:14 (208)

Data are mean (SD). Race time (minutes:seconds) is presented as the official score of the International Amateur Athletic Federation.

Table 3 Performance and changes in skinfold thicknesses after one, two, and three years of training in all runners

	Initial measure	After 1 year	After 2 years	After 3 years	p Value
Performance (IAAF score)	1046 (74)	1074 (54)*	1088 (55)*	1099 (67)*†	<0.001
Body weight (kg)	63.0 (10.3)	63.3 (9.7)	63.3 (9.8)	63.4 (10.5)	0.452
Triceps skinfold (mm)	6.7 (2.1)	6.6 (1.8)	6.7 (2.1)	6.6 (2.0)	0.741
Subscapular skinfold (mm)	8.1 (2.0)	8.2 (1.8)	8.3 (2.3)	8.2 (2.1)	0.818
Pectoral skinfold (mm)	4.8 (1.7)	4.6 (1.1)	4.7 (1.7)	4.6 (0.9)	0.679
Iliac crest skinfold (mm)	6.3 (2.2)	5.6 (1.4)	5.7 (1.3)	5.6 (1.4)	0.506
Abdominal skinfold (mm)	7.5 (2.3)	6.9 (2.4)*	7.2 (2.7)	7.2 (2.6)*	0.032
Front thigh skinfold (mm)	10.3 (4.2)	9.9 (4.1)*	9.5 (4.0)*	9.4 (4.2)*	0.008
Medial calf skinfold (mm)	5.2 (1.2)	5.0 (1.1)*	4.9 (1.3)*	4.6 (1.3)*†‡	0.001
Sum of six skinfolds (mm)	44.2 (10.8)	42.1 (9.2)	42.2 (10.2)	41.7 (10.2)*	0.028
E/T	1.04 (0.32)	1.07 (0.34)	1.03 (0.34)	1.02 (0.34)†	0.037

Data are mean (SD).
*Significantly different from the baseline measurement.
†Significantly different from the value recorded after one year of training.
‡Significantly different from the value recorded after two years of training.
IAAF, International Amateur Athletics Federation; E/T, extremity (triceps, front thigh, medial calf)/trunk (subscapular, iliac crest, abdominal) skinfold ratio.

RESULTS

Changes in skinfold thickness and performance with long term training

Tables 1–3 show changes in performance for each event and skinfold thicknesses after one, two, and three years of training. Training resulted in a significant increase in performance ($p<0.001$) and decreases in sum of six skinfolds ($p = 0.028$), abdominal ($p = 0.032$), front thigh ($p = 0.008$), and medial calf ($p = 0.001$) skinfolds, and E/T ($p = 0.037$). Except for E/T, the principal differences were observed after the first year. There were no significant differences in body weight, triceps, subscapular, pectoral, and iliac crest skinfolds (table 3).

Significant sex differences were observed for changes in E/T after one ($p = 0.030$), two ($p = 0.007$), and three years ($p = 0.026$) of training. In male runners, E/T decreased by −0.013, −0.069, −0.084 respectively, whereas in female runners these values increased by 0.087, 0.092, and 0.073.

There were no significant differences in these changes between sprint and endurance trained athletes, although important differences were observed according to the class of runner. Table 4 shows the change in baseline measures after three years of training in class A and class B runners. In the baseline measure, performance was higher in class A runners than class B runners, although there was no significant difference in skinfold measurements between the classification of runners. However, after a three year period, although there were no significant differences in performance and skinfold thicknesses in class A runners, class B runners significantly improved performance with concurrent changes in the sum of six skinfolds and front thigh and medial calf skinfolds.

Table 5 shows the pattern of response in terms of changes in weight and skinfolds and fat patterning (E/T) in those athletes who improved their performance and those athletes who did not improve performance after three years. In this respect, 30 runners had significantly increased their performance (3.11%), with significant concurrent decreases in the sum of six skinfolds, E/T, and abdominal, front thigh, and medial calf skinfolds after three years of training. Seven runners had significantly decreased their performance (3.40%), with significant increases in sum of six skinfolds and triceps, front thigh, and medial calf skinfolds after three years of training (table 5).

Similar results were obtained for shorter training periods—that is, between the third and second year of training. In this regard, 24 runners showed an increase in performance ($p<0.001$) which was associated with a significant decrease in sum of six skinfolds ($p = 0.019$), E/T ($p = 0.018$), and front thigh ($p = 0.009$) and medial calf ($p<0.001$) skinfolds. Thirteen runners had decreased in performance ($p = 0.007$) with an increase in subscapular skinfold ($p = 0.007$).

Table 4 Performance and changes in skinfold thicknesses induced after three years of intense athletic conditioning in class A and class B runners

	Class A runners (n = 18)			Class B runners (n = 19)		
	Initial measure	After 3 years	p Value	Initial measure	After 3 years	p Value
Performance (IAAF score)	1096 (48)	−0.0 (3.1)	0.887	999 (63)‡	3.7 (2.9)	0.000
Weight (kg)	63.8 (9.9)	0.3 (2.9)	0.349	62.2 (10.8)	0.5 (2.9)	0.107
Triceps skinfold (mm)	6.6 (2.7)	0.2 (1.2)	0.540	6.9 (1.4)	−0.4 (1.5)	0.303
Subscapular skinfold (mm)	8.3 (2.7)	0.4 (1.1)	0.118	7.8 (1.1)	−0.1 (0.8)	0.648
Pectoral skinfold (mm)	4.4 (1.3)	−0.1 (1.3)	0.187	5.2 (2.0)	−1.2 (2.9)	0.354
Iliac crest skinfold (mm)	5.7 (1.6)	0.2 (1.2)	0.499	6.8 (2.7)	−0.5 (1.6)	0.053
Abdominal skinfold (mm)	7.5 (2.8)	−0.2 (2.0)	0.132	7.6 (1.8)	−0.5 (1.4)	0.150
Front thigh skinfold, (mm)	9.8 (4.9)	−0.4 (2.8)	0.562	10.8 (3.5)	−1.4 (1.8)	0.003
Medial calf skinfold (mm)	5.1 (1.5)	−0.3 (1.0)	0.239	5.4 (0.9)	−0.9 (1.0)	0.001
Sum of six skinfolds (mm)	43.0 (13.3)	−0.4 (6.7)	0.817	45.3 (7.8)	−4.5 (5.8)	0.003
E/T	1.03 (0.38)	−0.01 (0.2)	0.420	1.06 (0.25)	−0.05 (0.2)	0.284

Data are mean (SD).
‡Significant differences between class A and class B runners ($p<0.001$).
IAAF, International Amateur Athletics Federation; E/T, extremity (triceps, front thigh, medial calf)/trunk (subscapular, iliac crest, abdominal) skinfold ratio.

Table 5 Performance and changes in skinfold thicknesses induced after three years of intense athletic conditioning in runners who showed an increase in performance (IPR) and runners who showed a decrease in performance (DPR)

	IPR (n = 30)			DPR (n = 7)		
	Initial measure	After 3 years	p Value	Initial measure	After 3 years	p Value
Performance (IAAF score)	1032 (74)	3.1 (2.3)	0.000	1106 (35)‡	−3.4 (2.8)	0.018
Weight (kg)	63.8 (9.9)	0.6 (2.7)	0.120	59.7 (11.8)	−0.2 (3.7)	0.499
Triceps skinfold (mm)	6.9 (2.1)	−0.4 (1.2)	0.066	6.1 (2.1)	1.3 (1.1)	0.027
Subscapular skinfold (mm)	8.2 (2.1)	0.1 (1.0)	0.713	7.3 (1.2)	0.5 (0.7)	0.078
Pectoral skinfold (mm)	4.8 (1.2)	−0.1 (1.0)	0.548	5.0 (3.2)	−0.5 (3.2)	0.343
Iliac crest skinfold (mm)	6.4 (2.4)	−0.9 (2.5)	0.115	5.8 (1.7)	0.1 (0.7)	0.666
Abdominal skinfold (mm)	7.5 (2.3)	−0.5 (1.5)	0.004	7.7 (2.4)	0.4 (2.2)	0.665
Front thigh skinfold (mm)	10.6 (4.3)	−1.6 (1.9)	0.000	9.3 (4.2)	1.8 (2.3)	0.018
Medial calf skinfold (mm)	5.4 (1.0)	−0.9 (0.8)	0.000	4.7 (1.8)	0.8 (0.5)	0.006
Sum of six skinfolds (mm)	44.9 (10.8)	−4.2 (5.6)	0.000	40.9 (10.7)	4.9 (5.1)	0.043
E/T	1.06 (0.32)	−0.08 (0.2)	0.013	0.98 (0.33)	0.2 (0.3)	0.097

Data are mean (SD).
‡Significant differences between runners who improved and decreased their performance runners ($p<0.001$).
IAAF, International Amateur Athletics Federation; E/T, extremity (triceps, front thigh, medial calf)/trunk (subscapular, iliac crest, abdominal) skinfold ratio.

Association between the changes in skinfold thicknesses and performance with long term training

Table 6 shows the relation between the changes in skinfold thicknesses and performance (% velocity) induced by intense athletic conditioning over one, two, and three years for the entire sample. It is notable that improvements in performance were consistently associated with a decrease in skinfold measurements. In general, these associations were true for male and female runners, sprint and endurance trained runners, and classification. Thus, after three years of training, changes in performance were related to changes in triceps ($r = -0.58$, $p = 0.003$), front thigh ($r = -0.71$, $p<0.001$), and medial calf ($r = -0.67$, $p<0.001$) skinfolds, sum of six skinfolds ($r = -0.64$, $p = 0.001$), and E/T ($r = -0.55$, $p = 0.005$) in the male runners. In female runners, changes in performance were related to changes in iliac crest ($r = -0.63$, $p = 0.021$), front thigh ($r = -0.62$, $p = 0.023$), and medial calf ($r = -0.78$, $p = 0.002$) skinfolds and the sum of six skinfolds ($r = -0.79$, $p = 0.001$). In sprint trained runners the changes in performance were associated with the changes in front thigh ($r = -0.61$, $p = 0.027$) and medial calf ($r = -0.70$, $p = 0.008$) skinfolds (fig 1) and sum of six skinfolds ($r = -0.81$, $p<0.001$). In endurance trained runners, a similar relation was presented for the triceps ($r = -0.61$, $p = 0.001$), front thigh ($r = -0.74$, $p<0.001$) (fig 2), and medial calf ($r = -0.66$, $p<0.001$) skinfolds, sum of six skinfolds ($r = -0.66$, $p<0.001$), and E/T ($r = -0.60$, $p = 0.02$). With regard to class A runners (n = 18), although performance did not change significantly (0.04%; IAAF score 1096 *v* 1098) after three years of training, the change in performance was nevertheless related to a change in triceps ($r = -0.70$, $p = 0.001$), front thigh ($r = -0.67$, $p = 0.002$) and medial calf ($r = -0.79$, $p<0.001$) skinfolds, sum of six skinfolds ($r = -0.71$, $p = 0.001$), and E/T ($r = -0.54$, $p = 0.020$). In the case of class B runners (n = 19), whose performance increased by 3.66%, the change in performance was related to changes in the front thigh ($r = -0.57$, $p = 0.011$) and medial calf ($r = -0.61$, $p = 0.006$) skinfolds and sum of six skinfolds ($r = -0.61$, $p = 0.005$).

With regard to only those runners who demonstrated an increase in performance after three years of training (n = 30), the change in performance was related to changes in the front thigh ($r = -0.60$, $p<0.001$) skinfolds and sum of six skinfolds ($r = -0.61$, $p<0.001$). In those runners with decreased performance in the same time frame (n = 7), the change in performance was related to the change in front thigh ($r = -0.75$, $p = 0.048$) and medial calf ($r = -0.89$, $p = 0.007$) skinfolds.

Table 6 Relation between the changes in skinfold thicknesses and performance (% velocity) induced over one, two, and three years of intense athletic conditioning for the male and female runners (n = 37)

	After 1 year *v* initial measure	After 2 years *v* initial measure	After 3 years *v* initial measure	After 2 years *v* after 1 year	After 3 years *v* after 1 year	After 3 years *v* after 2 years
Triceps	−0.25	−0.15	−0.51 p = 0.001	−0.06	−0.39 p = 0.019	−0.46 p = 0.004
Subscapular	−0.16	−0.05	− 0.31	−0.16	−0.17	−0.34 p = 0.039
Pectoral	−0.16	−0.06	−0.13	0.13	−0.21	−0.14
Iliac crest	−0.44 p = 0.007	−0.23	−0.36 p = 0.028	0.25	0.01	0.01
Abdominal	−0.15	−0.13	−0.29	0.10	−0.22	−0.22
Anterior thigh	−0.66 p<0.001	−0.50 p = 0.002	−0.63 p<0.001	−0.42 p = 0.01	−0.57 p<0.001	−0.58 p<0.001
Medial calf	−0.42 p = 0.009	−0.36 p = 0.029	−0.73 p<0.001	−0.34 p = 0.038	−0.42 p = 0.009	−0.38 p = 0.020
Sum of six skinfolds	−0.53 p = 0.001	−0.47 p = 0.003	−0.70 p<0.001	−0.19	−0.45 p = 0.005	−0.47 p = 0.003
E/T	−0.05	−0.17	−0.40 p = 0.014	−0.43 p = 0.008	−0.50 p = 0.002	−0.56 p<0.001

E/T, Extremity (triceps, front thigh, medial calf)/trunk (subscapular, iliac crest, abdominal) skinfold ratio.

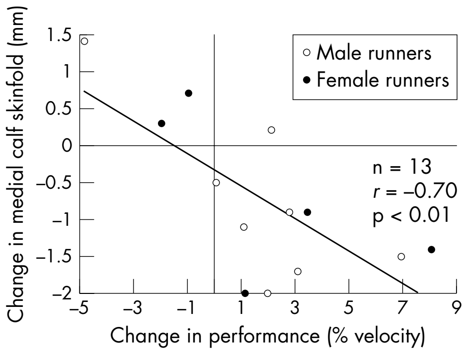

Figure 1 Relation between the changes in medial calf skinfold (mm) and performance (% velocity) induced after three years of intense athletic conditioning in sprint trained runners.

DISCUSSION

In a review of seasonal variation in fitness variables in competitive athletes, Koutedakis[16] reported that about 50% of studies suggested a lack of changes in subcutaneous fat during different seasons of training and/or competition in different sports. The possibility that the competitors involved reach optimal body fat levels for given genetic types may be a reason for this lack of seasonal changes, and the low initial body fat levels may be another reason for the lack of change during a season of high physical activity.[17 18] Significant body fat improvements may therefore be possible in certain competitors only if the initial fitness levels are relatively low, given that the response to training dosage is dependent on baseline fitness. Nevertheless, the changes in body fat and performance have not previously been correlated.

In this study, in sprint and endurance trained runners with an optimal performance and low initial body fat levels (the values of which were similar to those reported for Olympic athletes[19 20]), significant changes were observed in skinfold thicknesses after the athletic conditioning period.

It should be noted, however, that the level of performance was associated with the effect of training on skinfold thicknesses. The better runners (class A) did not significantly improve performance or show significant decreases in skinfold thicknesses, whereas the remainder of the runners (class B) showed an improved running performance and a decrease in skinfold thicknesses. The miniscule changes in performance of athletes who are already highly trained (class A runners) indicate that there are quite limited further performance enhancement benefits to all the training that elite athletes do, once they have reached their biological limits. This may explain why performance enhancing drugs are so attractive.

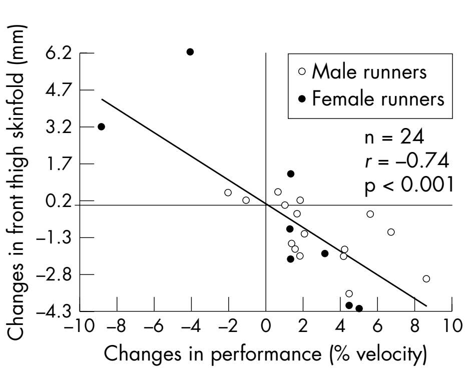

Figure 2 Relation between the changes in front thigh skinfold (mm) and performance (% velocity) induced after three years of intense athletic conditioning in endurance trained runners.

What is already known on this topic

- Research has indicated that appropriate sport specific levels of relative fat and fat-free weight are beneficial to performance in most sports
- Few studies have reported the relation between body fat or sum of skinfolds and running performance in homogeneous groups of elite athletes

What this study adds

- The loss of body fat appears to be specific to the muscular groups used during training
- The lower limb skinfolds may be particularly useful predictors of running performance

The differentiation in the changes in skinfold thicknesses with training among male and female runners is important. In male runners, a decrease in E/T was observed after the training period, whereas there was a small increase in this ratio in the female runners. We are unaware of physiological processes that may induce these results, but we consider that it is important to verify these observations in future studies with larger numbers of elite runners. Early studies on heterogeneous populations of subjects found that measurements of physical performance were negatively related to the amount of body fat and positively related to amounts of fat-free weight.[21 22] To the best of our knowledge, very few studies have reported the relation between body fat or sum of skinfolds with running performance in homogeneous groups of elite athletes.[5–7] In the latter cross sectional study of 184 elite runners, an apparent divergent association between trunk and extremity skinfolds with running performance was observed. The results of our study confirm these observations and provide evidence that this divergent relation is due to the effects of training. Whereas it was observed that the three year period of training resulted in decreases in the lower limb skinfolds, no significant changes were observed in trunk skinfolds. This pattern was observed in both sprinters and long distance runners of both sexes. These results suggest that the loss of body fat is specific to muscular groups used during training.

It is probable that lower extremity skinfolds facilitate running performance because a higher relative body mass distributed in the lower limbs would probably require greater muscular effort to accelerate the legs while running.[23] Also, in theory, the energetic expenditure would be higher.[24]

CONCLUSIONS

This study has assessed the relation between changes in skinfold thicknesses and running performance after three years of training. It provides support for the results of the cross sectional study of Legaz and Serrano,[7] which showed that the relation between skinfolds and the E/T ratio and performance may vary according to the running event and sex. Specifically, the study provides evidence that changes in the sum of six skinfolds, the medial calf and anterior thigh skinfolds, and the E/T ratio are related to changes in running performance, and that the loss of body fat is specific to muscular groups used during training. On the basis of these findings, we believe that it is essential that anthropometric assessment of top class athletes provides an evaluation of all skinfolds. It is notable that lower limb skinfolds are more highly correlated with measures of percentage body fat measures than upper body skinfolds in young adults.[25] Our study provides unique evidence that these measures may be particularly useful predictors of running performance.

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